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THE ROLE OF THE LEXICON IN PHONOLOGICAL VARIATION: AN INTERVIEW WITH MIRJAM ERNESTUS

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DE BONA – The reduction of phonological segments has challenged both abstract and exemplar models. In phsycholinguistic experiments, what have been some of the trends to look for evidence for words being stored as abstract representations or as exemplars?

ERNESTUS – The default assumption has always been that the pronunciation of a word is lexically stored in an abstract representation, consisting of a string of abstract phonological symbols, for instance phonemes. This assumption explains how listeners can identify a word if it is pronounced by new speakers, in new conditions: listeners just extract the phonological symbols from the acoustic signal and map the resulting string on the word strings stored in the mental lexicon. Furthermore, this assumption easily explains how speakers and listeners generalize over parts of words: because words are not treated as continuous streams of continually changing acoustic characteristics but as strings of discrete symbols, language users can generalize over parts of words. Interestingly, the assumption that storage is minimal and that computation plays an important role (among other tasks, finding the phonological

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units in the acoustic signal) fits well with what computers could do in the last part of the previous century: they were much better in computation than in storage.

Recent research strongly suggests that, for many words, the mental lexicon contains more than one single pronunciation variant. These studies (e.g., Ranbom & Connine, 2007; Bürki, Ernestus & Frauenfelder, 2010; Brand & Ernestus, in press) show that how quickly speakers and listeners process some variant of a word (e.g., French *plouse* instead of *pelouse* 'lawn') depends not only on the frequency of occurrence of the word (*pelouse*) but also on the frequency of occurrence of that pronunciation variant for that word (*plouse*). If listeners and speakers are sensitive to the frequencies of word pronunciation variants, they must have stored these frequencies, which makes it likely that they have stored the word variants themselves as well.

Note that the frequency effects cannot arise in comprehension if we assume that the lexicon does not contain the variants themselves, but, instead, for every word only one single pronunciation variant together with information about the frequencies of the phonological rules (e.g., schwa deletion) for that particular word that produce the variants. Word recognition would then involve reversing the phonological rules (e.g., schwa insertion undoing schwa deletion) and matching the resulting phonological string on the words in the mental lexicon. Only if the word is recognized, the frequencies of the phonological rules for that particular word (i.e. the frequencies of the variants) would become available, which is too late to affect the comprehension process (c.f. Brand & Ernestus, in press).

The question then arises whether the mental lexicon only contains pronunciation variants that differ from each other in phonological symbols (e.g., the presence versus absence of schwa) or also variants that differ from each other in a more subtle way (e.g., the exact quality of the stressed vowels). This would involve the storage of many pronunciation variants of each word. However, with the storage capacities of modern computers, this no longer seems implausible. The question has been addressed with perception experiments with identity priming. Words are typically recognized more quickly when they are repeated. Several studies (e.g., Craik & Kirsner, 1974; McLennan & Luce, 2005; Palmeri, Goldinger, & Pisoni, 1993) have shown that this is especially the case when the second time the word is uttered, it has (nearly) the same acoustic characteristics as the first time. These experiments thus show that listeners not only store the phonemic representation of the first occurrence of the word (the prime), but also its detailed acoustic characteristics. These acoustically detailed memory representations are typically referred to as exemplars.

An important question is whether exemplars are part of the mental lexicon, and therefore rather stable, or whether they are part of episodic memory, and therefore rather futile. Since exemplars effects are often not present, it is likely that exemplars are part of episodic memory (e.g., Hanique, Aalders & Ernestus, 2012; Nijveld, ten Bosch & Ernestus, 2015). Indeed, our work strongly suggests that exemplar effects show exactly those characteristics that are in line with what we know about episodic memory (Nijveld, ten Bosch, Ernestus, submitted). This issue is highly relevant for models of speech production and perception. For instance, if the mental lexicon only contains abstract representations of word pronunciations, the question arises what information these abstract representations exactly store. They probably store more than can be captured by phonemes, as appears, for instance, from the observation that phonetically gradient changes may show lexical diffusion (e.g., Bybee, 2002).

DE BONA – In most of your studies, lexical frequency is included as one of your variables to analyse data. Could you tell us a little bit about the corpora you use to get this information from and about the impact of this variable in different kinds of psycholinguistic experiments?

ERNESTUS – We derive our measures of lexical frequencies from different types of corpora (e.g. CELEX, for Dutch, English and German, Baayen, Piepenbrock, van Rijn; SUBTLEX, which is available for many languages including English, Van Heuven, Mandera, Keuleers, & Brysbaert, 2014). These corpora have in common that they are big (at least several millions of word tokens). Only large corpora can faithfully reflect small frequency differences between words. Moreover, frequencies of occurrence taken from large corpora are less sensitive to exactly which texts or speakers happened to be sampled, since large corpora contain many of them.

Different corpora may reflect different types of frequencies of occurrence. In Ernestus & Cutler (2015), we showed that auditory lexical decision is better predicted by frequencies in written texts than in speech. Our explanation is that written texts better show which words listeners know and, especially for the low frequency words, their exact frequencies of occurrence. We found different results for the production of conversational speech. In Torreira & Ernestus (2009), we found that [t] duration is best predicted by frequency measures that are derived from the very same corpus as where the [t]s to be modeled were taken from. These frequencies best reflect the words' probabilities in the given situation.

The size of the lexical frequency effect depends on the task that the speakers or listeners perform. The effects are typically larger when speakers / listeners have to identify words than when it is sufficient to recognize groups of words (as, for instance, in lexical decision). Furthermore, the effects are larger for words presented in isolation than in sentences, where the probabilities of the words given the surrounding words are typically more important (e.g., van Petten & Kutas, 1990).

DE BONA – Besides lexical frequency, contextual predictability is another lexical factor included in your analysis. How do you usually manage to get to its value to include it in your experiments?

ERNESTUS – There are three measures that reflect the predictability of a word given the preceding or following word. The first measure is the conditional probability of the word given its neighbouring word (the frequency of the word combination divided by the frequency of the neighbouring word). Second, we have used mutual information (e.g., Pluymaekers, Ernestus, & Baayen, 2005). Finally, we have just used the frequency of the word combination (that is, the frequency of the sequence of the target word and the preceding or following word; e.g., Torreira & Ernestus, 2009). An important advantage of this measure is that it can easily be extended to provide information about the predictability of the word given more than one preceding or following word (trigram frequency etc.).

The three measures should be highly correlated but we found several times that one was a good predictor for our phenomenon under investigation, whereas the other one was not. This may be due to noise in the corpora from which the measures are deduced; the different probabilities necessary to calculate the measures may differ in how precisely they can be computed on the basis of the given corpus (e.g., the probabilities of, frequent, neighbouring words may be more precise than those of, infrequent, target words).

DE BONA – Could you share with us some of the methods and statistical programs you use to analyse data in your corpus-based studies? In this regard, what recommendations would you give to a researcher in this area?

ERNESTUS – We use all kinds of statistical methods, including (generalized) mixed effects models, classification and regression tree analyses, and principal component analysis. I like to work in R, because this statistical package gives me the feeling that I am in complete control. There are lots of books on statistics in R and I recommend every student of linguistics to read them as early as possible in their careers.

Further, I recommend students to learn how to program (for instance, in Python) because this will save them a lot of time when they have to analyse their data. Moreover, computers are much better in performing tedious tasks than humans. Finally, I recommend researchers interested in speech production and phonetics to learn to use forced alignment, a procedure by which automatic speech recognition programs produce phonetic transcriptions of speech (see, e.g., Schuppler, Ernestus, Scharenborg & Boves, 2011). Although the resulting transcriptions may not be perfect, they give a good indication of how the words in the speech were pronounced.

DE BONA – What texts on the role of the lexicon in phonological variation do you consider essential to suggest to beginner researchers in the field?

ERNESTUS – I would recommend all the publications that I mentioned above and that are listed below.

1. Baayen, R. H., Piepenbrock, R., & van Rijn, H. (1993). *The CELEX lexical data base on CD-ROM*.
2. Brand, S. & Ernestus, M. (in press). Listeners' processing of a given reduced word pronunciation variant directly reflects their exposure to this variant: evidence from native listeners and learners of French. *Quarterly Journal of Experimental Psychology*.
3. Bürki, A., Ernestus, M. & Frauenfelder U.H. (2010). Is there only one "fenêtre" in the production lexicon? On-line evidence on the nature of phonological representations of pronunciation variants for French schwa words. *Journal of Memory and Language* 62, 421-437.

4. Bybee, J. (2002). Word frequency and context of use in the lexical diffusion of phonetically conditioned sound change. *Language variation and change*, *14*(3), 261-290.
5. Ernestus, M. & Cutler, A. (2015). BALDEY: A database of auditory lexical decisions. *Quarterly Journal of Experimental Psychology* 68, 8, 1469-1488.
6. Craik, F., & Kirsner, K. 1974. The effect of speaker's voice on word recognition. *Quaterly Journal of Experimental Psychology* 26(2), 274–284.
7. McLennan, C. T., & Luce, P. A. 2005. Examining the time course of indexical specificity effects in spoken word recognition. *Journal of Experimental Psychology: Learning, Memory and Cognition* 31(2), 306–21.
8. Nijveld, A. Ten Bosch, L. & Ernestus, M. (2015). Exemplar effects arise in a lexical decision task, but only under adverse listening conditions. In *Scottish consortium for ICPhS, M. Wolters, J. Livingstone, B. Beattie, R. Smith, M. MacMahon, et al. (Eds.), Proceedings of the 18th International Congress of Phonetic Sciences (ICPhS 2015). Glasgow: University of Glasgow*
9. Palmeri, T., Goldinger, S. D., & Pisoni, D. B. (1993). Episodic encoding of voice attributes and recognition memory for spoken words. *Journal of Experimental Psychology: Learning, Memory and Cognition* 19(2), 309–328.
10. Pluymaekers, M., Ernestus, M., & Baayen, R.H. (2005). Articulatory planning is continuous and sensitive to informational redundancy. *Phonetica* 62, 146-159.
11. Ranbom, L. J., & Connine, C. M. (2007). Lexical representation of phonological variation in spoken word recognition. *Journal of Memory and Language*, *57*(2), 273-298.
12. Schuppler, B., Ernestus, M. Scharenborg, O. & Boves, L. (2011). Acoustic reduction in conversational Dutch: A quantitative analysis based on automatically generated segmental transcriptions. *Journal of Phonetics* 39, 96-109
13. Torreira, F. & Ernestus, M. (2009). Probabilistic effects on French [t] duration. In *Proceedings of the 10th Annual Conference of the International Speech Communication Association (Interspeech 2009)*, pages 448-451. Causal Productions Pty Ltd.
14. Van Heuven, W. J., Mandera, P., Keuleers, E., & Brysbaert, M. (2014). SUBTLEX-UK: A new and improved word frequency database for British English. *The Quarterly Journal of Experimental Psychology*, *67*(6), 1176-1190.
15. Van Petten, C., & Kutas, M. (1990). Interactions between sentence context and word frequency in event-related brain potentials. *Memory & Cognition* 18(4), 380–393.